**PRELIMINARY DRAFT**

# Electricity Prices at U.S. Manufacturing Plants, 1963-2000

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**Abstract**

We study the distribution of electricity prices paid by U.S. manufacturing plants from 1963 to 2000. Our study relies on a newly constructed database that includes information for more than 48,000 manufacturing plants per year linked to additional data on electricity suppliers.

The shipments-weighted standard deviation of log electricity prices across manufacturing plants stood at 26% in 1963, fell sharply to 16% by 1978, and then changed little over the next 22 years. The "great compression" of price differentials in the 1960s and 1970s reflects a dramatic erosion of quantity discounts: the elasticity of price with respect to annual electricity usage declined from $-17.5\%$ in 1963 to $-6.5\%$ in 1976, and the fraction of overall dispersion accounted for by usage differentials shrank from 67% to 15%.

Despite efforts to improve the national electricity transmission grid during our sample period and to promote competition in wholesale and retail markets during the 1990s, the spatial dispersion in electricity prices is remarkably stable. The between-county standard deviation of log electricity prices ranges from about 11 to 13% over the past four decades, with no trend. Most of this spatial variation reflects average price differences among roughly 350 utilities that supply most of the electric power to the manufacturing sector. In turn, power source differences explain much of the average price differences among utilities.

**JEL codes:** L60, L94, Q40

**Keywords:** electricity price distribution; spatial price dispersion; price-quantity schedule

## 1. Introduction

Several developments and concerns have intensified interest in the performance of the U.S. electricity sector. These include a wave of restructuring and deregulation initiatives in the 1990s, major difficulties in the transition to more competitive electricity markets, inadequacies in the transmission grid for electric power, persistent regional differences in electricity prices and, most spectacularly, the California electricity crisis of 2000-2001. Borenstein (2002), DOE (2002) and Joskow (2003), among others, describe and analyze these issues.

Despite this intense interest, we lack detailed historical studies of prices paid by U.S. electricity consumers. As a result, there are large gaps in our knowledge about electricity pricing patterns amidst recent developments and in the preceding decades. These gaps hamper our ability to place recent developments in historical perspective, to assess the impact of restructuring and regulatory changes on electricity consumers and to reach informed judgments about the wisdom of alternative directions for future reforms.

To help address these gaps, we construct a new micro database and use it to examine the distribution of electricity prices paid by U.S. manufacturing plants from 1963 to 2000.[1] The database includes information on electricity expenditures and purchases (watt-hours) for more than 48,000 manufacturing plants per year, which we link to additional data on the utilities that supply electricity. The database relies on

[1] Historically, industrial purchasers accounted for a large percentage of retail electricity sales – 48 percent in 1963, the start of our sample period. That percentage declined over time, but industrial purchasers still account for 31 percent of retail sales as of 2000 (EIA, 2001). In turn, manufacturing plants account for the lion's share of electricity purchases by the industrial sector and, as we show below, average electricity prices for the manufacturing sector are similar to average prices for the industrial sector as a whole.

calendar-year measures of electricity expenditures and purchases by plants in the Annual Survey of Manufactures (ASM). These data are available for 1963, 1967 and annually since 1972.

We focus on log prices for the usual reasons and because of the nature of the variable costs associated with electricity transport and delivery. In particular, both electricity transmission over power lines and the process of transforming voltage levels involve costs in the form of electrical energy dissipated as heat energy. In this respect, the delivery of electricity to end-users fits the iceberg model of transport costs. Moreover, the dissipation of electrical energy rises with transmission distance, other things equal, so that spatial price differentials are aptly described in log terms.

Figure 1 shows a "great compression" in the log price distribution from 1963 to the late 1970s. The shipments-weighted standard deviation of log electricity prices fell from 26% in 1963 to 16% by 1978, and the 90-10 price differential fell from 51 log points in 1967 to 33 log points in 1979. To the best of our knowledge, we are the first to document this great compression in the distribution of electricity prices. A key goal of the paper is to explore the factors that underlie this development and the later behavior of electricity price dispersion.

We show below that the great compression reflects a dramatic erosion of quantity discounts on electricity purchases. The elasticity of price with respect to annual electricity purchases (usage) declined sharply in magnitude from $-17.5\%$ in 1963 to $-6.5\%$ in 1976. Usage differentials account for 67% of overall price dispersion among manufacturing plants in 1963, but only 15% by 1975. The flattening of electricity price-quantity schedules clearly predates the Public Utility Regulatory Policy Act (PURPA) of 1978, which sought to restrict quantity discounts unless justified by lower costs of transmission and distribution to larger electricity users.[2]

We also investigate the spatial distribution of electricity prices among states, counties and utilities. To our surprise, the overall spatial dispersion of log electricity prices is highly stable from 1963 to 2000. For example, the between-county standard deviation of log electricity prices ranges narrowly from about 11 to 13% during the past four decades, with no trend. However, the spatial structure of electricity prices has shifted over time, as described below. In work under development, we seek to explain the spatial structure of electricity prices in terms of local market characteristics such as population density and supplier characteristics such as generating sources (coal, oil, gas, hydro, nuclear and other) and participation in wholesale electricity markets.

The paper proceeds as follows. Section 2 provides background on the electric power industry, selected regulatory developments, and changes over time in the real cost of electricity and other forms of energy. Section 3 describes the database. Section 4 decomposes the variance of log electricity prices in terms of geographic units, electricity usage level and the identity of the electricity supplier. Section 5 examines electricity price-quantity schedules and their role in the great price compression seen in Figure 1. Section 6 investigates spatial price differentials, and Section 7 concludes.

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[2] PURPA had no apparent impact on average price-quantity schedules for electricity purchases by U.S. manufacturing plants. We are currently investigating whether PURPA nevertheless brought about a flattening of price-quantity schedules at utilities that had not already curtailed quantity discounts by 1978. We are also investigating whether the end of plentiful generating capacity explains the timing of the shift towards flatter price-quantity schedules at individual utilities.

## 2. Background and Context

From its inception in the 1880s until the mid 1960s, the electric power industry enjoyed a "golden era" (Hirsh, 1999).[3] Generating technology improved rapidly, capacity was plentiful, and electricity prices fell. Utilities offered promotional block pricing with prices per kilowatt-hour (kWh) that declined with purchases. Stimulated by falling real prices, quantity discounts, and new electrical appliances and machinery, electricity consumption grew rapidly after World War II (Hirsh, 1989, Chapter 4). This "golden era" came to an end by the late 1960s. Previously unrecognized technological and metallurgical barriers hampered progress in the creation of better electric generators. Inadequately tested designs were put into use, and reliability problems at generating plants became more frequent. Generators that had been operating below capacity with decreasing average costs were pushed to their limits by the 1970s.[4]

Economic factors exacerbated the technological problems facing the industry in the 1970s. Electricity demand varies widely depending on local economic conditions, season of the year, time of day, temperature and other factors. Uncertain demand, the high cost of electricity storage and, historically, the absence of peak-load pricing at the retail level made it difficult to project electricity consumption and generating requirements. Accurate projections became even more difficult in the 1970s because of large fluctuations in output, industrial production and inflation. Prices rose sharply for coal and oil, major fuel sources for electricity generation, and there were major

[3] Others share this view. For example, Joskow (1989) writes "During the 1950s and most of the 1960s the electric power industry attracted little attention from public policy makers. It experienced high productivity growth, falling nominal and real prices, excellent financial performance, and little regulatory or political controversy."
[4] See Chapters 7 and 8 of Hirsh (1989) for a detailed description of the technological difficulties facing the electric power industry in the late-1960s and 1970s.

disruptions in petroleum supplies. The OPEC Oil Embargo of 1973 precipitated a dramatic rise in oil prices, as did the Iranian Revolution of 1979. Large fluctuations in the user cost of capital during the 1970s also discouraged the construction of new generating plants.

Concerns about air and water pollution from conventional power plants and about safety at nuclear plants led to several pieces of legislation in the late 1960s and 1970s that raised costs in the electric utility industry and hampered its operation and development.[5] The National Environmental Policy Act of 1969 required utilities to prepare and defend environmental impact statements for all new generator sites. The Clean Air Act of 1970 restricted air pollutants at electricity-generating plants and encouraged utilities to switch from coal to cleaner burning oil or natural gas. The Federal Water Pollution Control Act of 1972 limited waste discharge, and the Resource Conservation and Recovery Act of 1976 set forth standards for utility waste products. The Energy Supply and Environmental Coordination Act of 1974 authorized the federal government to prohibit purchases of natural gas and petroleum by utilities. Finally, the Clean Air Act Amendments of 1977 imposed more stringent restrictions on emissions from electricity-generating plants.

The upshot of these technological, economic and regulatory developments is that the era of declining electricity prices and plentiful capacity drew to a close by 1970. Real electricity prices began to rise after 1973 (Figure 2), [6] partly because of sharply higher costs for the fossil fuels that powered many of the generating plants (Figure 3).[7]

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[5] Appendix A in EIA (2000c) discusses the legislation summarized below in this paragraph.
[6] The electricity price series in Figure 2 for residential, commercial and industrial sectors are from the Energy Information Administration (EIA), and the two price series for the manufacturing sector are

In 1978, several important pieces of legislation passed as part of President Carter's National Energy Plan. Among other things, Carter's plan included the gradual removal of price controls on oil and natural gas, restrictions on the use of oil and natural gas by new and existing generating plants, and rate reform for electric utilities (Hirsh, 1999). Congress split Carter's plan into five separate acts, modified them and eventually passed all five on November 9, 1978.[8] Of these, the Public Utility Regulatory Policy Act (PURPA) had the biggest impact on electricity markets.[9] The rate-reform aspects of PURPA were hotly debated in Congress (Hirsh, 1999, Chapter 4), but in their final form they required only that state regulatory agencies "consider" implementing various reforms that included an end to promotional pricing structures.[10] PURPA Section 210

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constructed from the ASM micro data used in our study. The EIA data rely on reports from electric utilities. EIA prices are calculated as revenue from retail electricity sales divided by kilowatt hours delivered to retail customers, and then deflated by the BEA implicit price deflator for GDP. The ASM data rely on reports from electricity customers (manufacturing plants), and they are deflated in the same way. In the EIA data, the industrial sector encompasses manufacturing, mining, construction and agriculture.

[7] The real prices for fuels in Figure 3 were deflated using the BEA implicit price deflator for GDP. Prices were converted from physical units to Btu using EIA approximate annual conversion factors (EIA, 2001a, Appendices).

[8] The four other acts derived from the National Energy Plan are the "Energy Tax Act of 1978" (Public Law [PL] 95-618), the "National Energy Conservation Policy Act" (PL 95-619), the "Powerplant and Industrial Fuel Use Act of 1978" (PL 95-620), and the "Natural Gas Policy Act of 1978" (PL 95-621). These can be found in the U.S. Code Database at http://law2.house.gov.

[9] This view is widely held. For example, see pages 127-128 of Joskow (1989), pages 206-207 of White (1996), and Chapters 4 and 5 of Hirsh (1999).

[10] PURPA is PL 95-617. A summary of PURPA describes some key characteristics of the law:

- "Requires State regulatory authorities and each nonregulated utility to consider how implementation of standards imposed by this Act would affect each utility and its consumers in terms of energy conservation, energy efficiency, and equitable rates and to determine whether or not to implement such standards.
- Requires that electric utility rates for each class of electric consumers shall be based on the costs of providing such service to such classes.
- Prohibits the use of declining block rates unless the costs of providing services to a particular class decreases as kilowatt-hour consumption increases.
- Establishes time of day and seasonal rates to account for variations in load curves, and establishes standards relating to interruptible rates and local management techniques.
- Directs the Commission to prescribe rules requiring electric utilities to offer to sell electric energy to any qualifying cogenerator, or small power producer and to offer to purchase electric energy from such entities.

required utilities to buy from and sell power to non-utility "qualifying facilities."[11] The goal of Section 210 was to draw non-utilities, such as cogeneration plants and renewable resource plants, into the electric power market (Gordon, 1982). In this respect, PURPA and later legislation appear to have had a major impact. By 1999, non-utilities owned 19.8 percent of the electric generating capacity in the U.S. (EIA, 2000a, p.1).

Wholesale trade in electricity markets (electricity sold for resale) became more active over time. From 1986 to 1992, wholesale trade already amounted to 30 to 40 percent of final electricity sales. The Energy Policy Act of 1992 (EPACT) sought to promote greater competition and participation in wholesale markets and to unbundle the price of electrical power from the price for transmission and distribution services.[12] EPACT, FERC Orders 888 and 889 (issued in 1996) and various state-level actions during the 1990s also stimulated growth in the wholesale trade of electricity. These legislative and regulatory actions helped to create a new class of power producers (non-utility qualifying facilities) with access to transmission and exemption from many traditional restrictions on public utilities.

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- Requires the Commission to prescribe rules exempting qualifying cogenerators and small power producers in whole or in part from the Federal Power Act and/or the Public Utility Holding Company Act."

This summary is from the U.S. government "Thomas" on-line archives and can be found at http://thomas.loc.gov/cgi-bin/bdquery/z?d095:HR04018:@@@L|TOM:/bss/d095query.html|.
See Gordon (1982) for a detailed description of PURPA.

[11] See Chapters 4 and 5 of Hirsh (1999) for a detailed description of Section 210, summarized briefly here. Section 210 of PURPA made special rules and exemptions for "qualifying facilities" (QFs). QFs did not have to be regulated in the same way as electric utilities (PUHCA exemption). FERC was given the power to interpret PURPA, and they set up the following requirements that were favorable for QFs:

- Utilities had to buy the electricity produced by the QFs.
- QFs received 100% of the utilities "avoided cost" for the electricity they sold to the utilities. FERC defined "avoided cost" as the cost the utility would have incurred had it produced the electricity itself. There was significant debate about how to determine this "cost".
- QFs could purchase supplemental and backup power from the electric utilities at normal retail rates. Since most utilities were charging rates based on average cost, QFs could buy the commodity they were selling at a high price for a much lower price from the utilities. This provided the QFs with arbitrage opportunities and further encouraged entry.

Several states have undertaken efforts, not always successful, to introduce greater retail competition in the electricity sector. According to Joskow (2003, page 2), the "first retail competition programs began operating in Massachusetts, Rhode Island and California in early 1998 and spread to about a dozen states by the end of 2000."[13] Since these developments on the retail side of the electricity sector come at the tail end of the period covered by our data, they are not the main object of our attention.

In summary, the regulation of the electric power industry has undergone significant changes since the late 1970s. PURPA discouraged promotional block pricing and encouraged electricity generation by non-utilities and nontraditional power sources. EPACT, FERC Orders 888 and 889 and state-level actions promoted additional growth of wholesale electricity markets, partly by assuring transmission access for non-utility power producers. Many states acted to partly deregulate wholesale and retail markets in the 1990s. Most of these deregulation efforts are in their early stages, but there has been substantial growth of wholesale trade in electricity markets over the course of the 1990s.

## 3. The Data

Our data on electricity prices and quantities come from the 1963, 1967, and 1972-2000 Census of Manufactures (CMF) and Annual Survey of Manufactures (ASM). The ASM is a series of five-year panels that are refreshed by births as a panel ages. Large manufacturing plants with at least 250 employees are sampled with certainty, and smaller

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[12] See White (1996) and Joskow (1997).

[13] The Energy Information Administration (EIA) collected information on competition in retail sales of electricity prior to 1998. "We [EIA] collected information from electric sales to customers who selected competitive energy service providers, beginning in 1996 – related mostly to pilot programs underway in New Hampshire…and Illinois. The total sales amount in 1996 was only about 3.3 million megawatthours of energy sold, growing to about 5.85 million megawatthours in 1997 in California, Idaho, Illinois, Massachusetts, Missouri, New Hampshire, New York, Oregon, Pennsylvania, Rhode Island and Washington State." (Rodney Dunn, EIA Electric Power Industry Specialist, personal communication, October 16, 2003).

plants with at least 5 employees are sampled randomly with probabilities that increase in the number of employees.[14] ASM plants account for about one-sixth of all manufacturing plants and about three-quarters of manufacturing employment.

ASM plants report the quantity of and expenditures on purchased electricity during the calendar year.[15] We calculate the plant-level price as annual purchases divided by annual expenditures. All statistics reported in this study make use of ASM sample weights, so that our results are nationally representative. The Data Appendix describes several issues with ASM-based electricity price and quantity measures that we identified and addressed in the course of preparing this study. A companion paper by Davis et al. (2003) treats these and other data issues in much greater detail.

We created two measures of where a plant fits in the distribution of electricity purchases. For one measure, we first pooled observations over all plants within a year and then computed deciles of the resulting distribution of electricity purchases. We then assigned each plant-year observation a decile rank from 1 to 10 based on where it fits in the pooled distribution for that year. For a second measure, we assigned centile ranks based on where a plant-year observation fits into the distribution of purchases in that same year.

We merged the ASM-based data with the Annual Electric Utility Report for 2000, which is supplied by the Energy Information Agency (EIA) in its EIA-861 file. The 861 file includes state-level data on revenue from industrial customers for each electric utility,

[14] The number of employees required to be a certainty case is lower in 1963 and 1967. In 1963, all plants in a multi-plant firm with 100 or more employees were sampled with certainty. The same was true in 1967 except for plants in the apparel manufacturing (SIC 23) and printing and publishing industries (SIC 27), which had a certainty threshold of 250 employees.

the North American Electric Reliability Council (NERC) region in which the utility operates, and a list of counties served by the utility.[16] Figure 4 shows the 12 NERC regions in the U.S.[17]

Counties are served by as many as 12 electric utilities.[18] For the purposes of our analysis, we created a "big" utility variable, defined as the utility with the most statewide revenue from industrial customers among the utilities that serve the county.[19] For parts of our analysis, we then match the big utility for the county to the manufacturing plants that operate in the county. Where available, we also exploit publicly available information on the identity of manufacturing plants that purchase electricity directly from the Tennessee Valley Authority or other public power authorities. Our matching procedure is imperfect, because it does not always correctly identify the utility that supplies electricity to the manufacturing plant.

Table 1 reports several characteristics of our merged database. The database contains more than 1.8 million plant-level observations over the period from 1963 to 2000. There are 3,036 counties with manufacturing plants and 347 "big" utilities, 10 of which are accounted for by public power authorities that supply electricity directly to

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[15] Even in Census years, only ASM plants are asked about the quantity of purchased electricity.

[16] To the best of our knowledge, data on the list of counties served by each electric utility are not available prior to 1999. Hence, we apply each utility's county list for 2000 to all years considered in our study.

[17] There are three major power grids within the continental U.S.: the Western interconnection (WSCC), the Texas interconnection (ERCOT), and the Eastern interconnection (all other NERC regions in the continental U.S.). The ability to transport electricity between these grids is limited (EIA, 1998, p. 7).

[18] This number excludes electric utilities with zero statewide industrial revenue. In our electricity price database, there are 459 counties served by a single utility, 780 served by 2, 792 served by 3, 536 served by 4, 261 served by 5, 128 served by 6, 51 served by 7, 15 served by 8, 4 served by 9, 5 served by 10, 3 served by 11, and 2 counties served by 12 utilities.

[19] For multi-state utilities, we assign up to one big utility code for each state in which it operates. Thus, by construction, no "big" utility operates in more than one state. We adopted this approach because of the important role played by states in electric utility regulation and electricity pricing.

manufacturing plants.[20] The coefficient of variation for electricity purchases is about 3, the 90-10 quantile ratio is about 380, and the 99-1 quantile ratio exceeds 10,000. The range of electricity purchases in the database is enormous.

**4. Electricity Price Dispersion and Variance Decompositions**

We decompose the variance of electricity prices between and within groups defined by electricity usage levels (i.e., annual purchases) and location. Electricity usage is measured by the decile and centile groups described in Section 3. Location is defined in terms of county, big utility area (BU), state or NERC region.

Equation (1) shows the variance decomposition for any given year:

$$\begin{aligned} V &= \sum_{e} s_e \left(lp_e - \overline{lp}\right)^2 = \sum_{l} \sum_{e \in l} s_e \left(lp_e - \overline{lp}\right)^2 \\ V &= \left( \sum_{l} s_l \sum_{e} s_e \left(lp_e - \overline{lp_l}\right)^2 \right) + \left( \sum_{l} s_l \left(\overline{lp_l} - \overline{lp}\right)^2 \right) \\ V &= \quad V_{wl} + V_{bl} \end{aligned} \tag{1}$$

where $lp_e$ is the log price of electricity for plant $e$, $s_e$ is the weight for plant $e$, $\overline{lp}$ is the weighted mean log price for all plants, $\overline{lp_l}$ is the weighted mean log price for plants in group $l$, $s_l = \sum_{e \in l} s_e$ is the sum of weights for plants in group $l$, $V_{wl}$ is the average within-group variance, and $V_{bl}$ is the between-group variance. Table 2 reports this variance decomposition for selected years and various grouping criteria, in each case using the product of the ASM sample weight and the value of the plant's shipments for the $s_e$. In other words, the variance decompositions are computed on a shipments-weighted basis.

[20] Only a small number of manufacturing plants purchase electricity directly from public power authorities, but they tend to be plants with very large electricity purchases.

According to Table 2, the standard deviation of log electricity prices across manufacturing plants stood at 26% in 1963, fell sharply to 16% by 1977, and then changed little over the next 23 years. This is the same pattern we highlighted in Figure 1.

Table 2 also reveals that declining price differentials among electricity usage categories are largely responsible for the great compression in the log price distribution from 1963 to the late 1970s. As reported in the table, usage centiles account for 67% of overall price dispersion in 1963, but only 34% in 1972 and 17% in 1977. The standard deviation in log prices across usage centiles falls from .21 in 1963 to less than .07 in 1977. The standard deviation of usage differentials then rose modestly to .09 in 1997.

In contrast to the sharp compression of usage differentials after 1963, the standard deviation of log electricity prices across U.S. counties ranges narrowly from roughly 11 to 13% over the past four decades, with no trend. Figure 5 shows this same result more graphically, making clear that spatial price differentials contributed nothing to the great compression in the overall distribution of log electricity prices.

Figure 6 shows the overall and between standard deviations for county, big utility, usage centiles and big utility crossed with usage centiles. It is worth emphasizing that the 347 big utilities account for almost as much of the variation in electricity prices as the 3,036 counties. Together, big utility and usage centile account for a large part of the variation in electricity prices throughout the entire sample period. Whether measured by utility or county effects, spatial price dispersion rises after the early 1970s, peaks around 1980, declines gradually until the late 1980s, then rises modestly again.

Both Table 2 and Figure 6 show that the main force behind the great compression in the electricity price distribution through the late 1970s is the collapse in price differentials among groups of manufacturing plants with different electricity purchase levels. In the next section, we explore electricity price-quantity schedules in detail.

## 5. Electricity Price-Quantity Schedules

The delivery of electricity to end users requires generating facilities, transmission lines and transformers (to alter voltage). Marginal costs of generation depend on several factors including power source and generator efficiency. Marginal costs of delivery depend on the physical characteristics of the transmission grid and distribution system.

Electrical energy dissipates as heat energy during transmission and in the process of transforming voltage levels. One way to lower energy losses and transmission costs is to reduce the resistance to electric current.[21] The resistance of a wire depends on its physical characteristics such as material type, length, and thickness. Resistance increases with the length of the wire and decreases with thickness. Another way to lower transmission costs is to rely on high-voltage power lines that involve less dissipation as heat energy. However, high voltage levels are dangerous, so transformer stations near the final delivery point are typically used to step down voltage levels for end users. The process of transforming voltage levels also involves some dissipation of electrical energy.[22]

Taking this basic physics into account, there are several reasons why electricity might be less costly to supply to large electricity purchasers: (a) high-voltage transmission lines can lead all the way to the plant's "doorstep", cutting down on

[21] See Halliday et al. (1992) for a discussion of the basic physics of electricity.
[22] Transformers are used to convert high voltage electricity to low voltage electricity and vice versa. Those that convert from high to low voltage are often called "step-down" transformers. Some power is lost when the electricity is transformed due to eddy currents, which are currents induced by the magnetic field in the iron core of the transformer. The eddy currents heat up the core of the transformer and the energy in that heat is lost.

transmission costs; (b) a large power consumer might operate some equipment at high voltage levels, circumventing or reducing the need for step-down transformers and complex distribution networks; (c) plants that use large amounts of power may operate and maintain their own step-down transformers in any event, relieving the utility of this task and associated costs; (d) large electricity users may locate close to power generators to minimize transmission losses; and (e) some large electricity users may accept interruptible power provisions in exchange for lower prices. In short, there are good reasons to anticipate some degree of quantity discounts in electricity price-quantity schedules, even if generating costs are flat or rising. During the "golden era" of the electric power industry, declining average and marginal costs of generation provided another potentially important reason for quantity discounts.

We now consider empirical evidence on electricity price-quantity schedules for manufacturing plants and changes in these schedules over time. Figure 7 shows the average log price by usage decile from 1963 to 2000.[23] As of 1963, the average price for plants in the lowest usage decile was almost 70 log points higher than in the highest decile. Smaller price differentials are apparent throughout the entire distribution of electricity usage. Usage-level price differentials shrink dramatically during the 1960s and the first half of the 1970s. By 1978, the year when PURPA was enacted, the dramatic erosion in quantity discounts was already complete. Modest quantity discounts persisted after 1978 and throughout the period until 2000. The average price gap between the biggest electricity users and the next group remains large after 1978,

[23] The sharp compression in the price distribution at the lower usage deciles after 1989 reflects a data problem that we are currently working to resolve. This data problem mainly affects smaller plants and, hence, does not have much effect on the shipments-weighted and purchase-weighted statistics and analyses that we report elsewhere in the paper.

amounting to about 10 log points in 2000. Price differentials are small over the rest of the distribution.

Figures 8 provide a more detailed look at the price-quantity schedules for selected years. Figure 8a plots the mean log price by usage centile, and Figure 8b plots the fitted relationship between price and usage based on plant-level regressions of log price on a quartic polynomial in log purchases.[24] The panels show a flattening of the price-quantity schedule through 1978 and little change in the shape of the schedule after 1978. Figure 8b also suggests that the price-quantity schedule is well approximated as a log linear relationship, a fact that we exploit below.

It is worth remarking that what appear to be quantity discounts could, in fact, be spatial dispersion in disguise. If manufacturing plants that purchase larger amounts of electricity are more likely to locate in areas served by utilities with relatively inexpensive power, then we can find a negative relationship between electricity price and usage even if all utilities offer flat price-quantity schedules. More generally, any tendency by larger electricity users to buy power from utilities with lower prices contributes to a negative price-quantity relationship. We refer to this phenomenon as “spatial sorting”.

Figure 9 displays the time series of slope coefficients from cross-sectional plant-level regressions of log electricity prices on log electricity purchases. In order to distinguish between spatial sorting and true quantity discounts at the utility level, one regression specification includes controls for big utility and one does not. Figure 9 confirms the dramatic flattening of price-quantity schedules between 1963 and the late 1970s, and it conveniently summarizes the size of the quantity discount by year. The

[24] We trimmed the bottom and top 2% of the usage distribution prior to fitting and plotting the curves shown in Figure 8b.

elasticity of price with respect to annual purchases stood at $-17.5\%$ in 1963, fell to about $-11.5\%$ in 1972 and diminished further to about $-6.5\%$ by 1978.

Figure 9 also shows that spatial sorting is a small part of the explanation for the negative relationship between price and quantity. Prior to the mid 1970s, the slope coefficients are virtually unaffected by the inclusion of big utility fixed effects, indicating that spatial sorting played no role in the negative price-quantity relationship. Starting in the mid-1970s, there is evidence of systematic spatial sorting of larger electricity users to areas served by utilities with lower electricity prices. But even after 1975 the spatial sorting effect is modest, accounting for only about 1 to 1.5 percentage points of an elasticity that fluctuates in the range of $-6.5\%$ to $-9.5\%$.

The within-utility elasticity of price with respect to annual purchases reaches its smallest value of $-5.0\%$ in 1981 and becomes gradually larger after the early 1980s. In the years after 1985, the within-utility elasticity of price with respect to purchases is always larger in magnitude than its value in 1977, the year prior to PURPA. This evidence reinforces our view that the rate-reform provisions in PURPA had little impact on electricity price-quantity schedules – at least for manufacturing customers.

## 6. The Spatial Structure of Electricity Prices

Regional price differences for electricity are often cited as a key driving force behind efforts during the 1990s to reform the electricity sector (White, 1996, and EIA, 2000c). Yet the results presented above show that the spatial dispersion of electricity prices has been remarkably stable over the last four decades. Indeed, Figure 5 shows a slight increase in the spatial dispersion of electricity prices since 1963 and since 1985. Evidently, reform efforts have not mitigated overall spatial price dispersion.

The spatial structure of prices has changed over time. To depict some of these changes, Figure 10 displays average log price deviations from the U.S. mean for selected states. Prices in California were modestly above the national average in the 1960s and early 1970s, but then rose steadily to reach a level 25 log points above the national average in the 1990s. Many states in the Southwest, Mountain and Midwest regions have experienced declining relative prices in recent decades. For example, relative prices in Illinois and Michigan were about 15 log points above the national average in the 1960s but fell to just above the national mean by 2000. For many states on the east coast, relative electricity prices have remained high throughout the past four decades. Washington and Idaho, two states that rely heavily on hydro power, show low relative prices throughout the past four decades but also much volatility.[25] In particular, both states experienced abrupt drops in the relative price of electricity during the mid 1970s, followed by a long period of rising relative prices. This pattern indicates that, in response to the general rise of energy costs after 1973, electricity prices responded with a considerable lag in states that did not rely much on fossil fuels for power generation.

Figures 11 and 12 provide more systematic evidence about mobility over time within the spatial price distribution, and at a finer geographic level. These figures display scatter plots and linear regression fits for county and big utility fixed effects across pairs of years.[26] The scatter plots and regression fits show considerable persistence in the

[25] Washington and Idaho generated 86.7% and 99.9%, respectively, of their electricity from hydropower in 1973. In contrast, Connecticut and Massachusetts generated 79.2% and 83.4%, respectively, of their electricity from oil and natural gas powered generating plants in 1973. We calculated these figures from EIA (2001b).

[26] For any given year, we computed county fixed effects as deviations of the county mean log price from the national mean log price. We calculated big utility fixed effects in an analogous manner. In the scatter plots and in fitting the regression lines, we omitted counties and utilities that did not meet disclosure requirements because of too few underlying plant-level observations. In the regressions, we weighted each included observation by the square root of the number of plants used to compute the fixed effect.

spatial price structure over five-year intervals. R-squared values range from .53 to .80 for the county-level regressions and from .64 to .85 for the utility-level regressions. Slope coefficients are also high, ranging from .66 to 1.0.

Two other aspects of Figures 11 and 12 strike us as noteworthy. First, both figures show the lowest R-squared values for the 1972-1977 interval, which encompasses the first oil price shock and a dramatic rise in the real cost of fossil fuels (Figure 3). The R-squared values are also relatively low for the 1977-1982 interval, during which the real cost of oil and natural gas, but not coal, continued to rise sharply. These results confirm the more impressionistic evidence in Figure 10 that rising fossil fuel prices in the 1970s and early 1980s disturbed the spatial structure of electricity prices.

Second, the 1990s and the latter part of the 1980s show greater stability in the spatial price structure than earlier decades. Moreover, the regression slopes fitted to these intervals are by no means on the low side, as one might expect if increasing regional or national integration of electricity markets caused spatial price differentials to revert toward the mean. These findings imply that the rapid growth in wholesale electricity trade since the mid 1980s and the vigorous federal and state efforts to promote wholesale electricity markets have not led to a compression of spatial price differentials, or even had much effect on the spatial structure of prices. It is certainly possible that a narrowly focused geographic analysis would uncover evidence of spatial price convergence within particular regions, but any such effects are not sufficiently powerful or pervasive to reduce overall spatial dispersion (Table 2 and Figure 5), noticeably disturb the spatial structure of prices (R-squared results in Figures 11 and 12), or drive outliers in the spatial price distribution to the national mean (slope coefficients in Figures 11 and 12).

In work under development, we are seeking to quantify some of the major determinants of spatial price differences. There are many candidate factors, which differ in their ease of measurement. Some states, California for example, have stringent environmental laws that raise the cost of electricity generation and transmission. Regional differences in the relative importance of hydro, nuclear and the mix of fossil fuels clearly have major and time-varying effects on spatial differences in the cost of electricity generation. Figure 3 shows the pattern of real prices for coal, natural gas, and crude oil from 1960 to 2000. Coal has by far the most stable prices, with coal prices rising significantly in the 1970s and then declining slowly. Crude oil and natural gas prices are much more volatile. Other potentially important factors include state and local taxes on purchased electricity, rate-setting procedures, and the age and efficiency of the distribution network.

## 7. Conclusions

Our main findings are summarized as follows:

- The distribution of log electricity prices underwent a great compression from 1963 to the late 1970s. Thereafter, and through 2000, there was little change in the overall dispersion of electricity prices paid by manufacturing plants.
- The great compression reflects a dramatic flattening in electricity price-quantity schedules. The average elasticity of price with respect to annual electricity purchases fell (in magnitude) from -17.5% in 1963 to -6.5% in 1976.
- This dramatic erosion of quantity discounts clearly predates the rate-reform provisions enacted by PURPA in 1978, and PURPA had no apparent impact on average price-quantity schedules.
- Quantity discounts, and the flattening of price-quantity schedules over time, occur within utilities. The spatial sorting of large electricity users to areas served by utilities with cheaper electricity plays no role in the negative price-quantity relationship prior to the mid 1970s and only a very modest role thereafter.
- There are no large secular movements in the spatial dispersion of log electricity prices over the 1963-2000 period, and only mild year-to-year fluctuations. Spatial dispersion rose somewhat during the mid 1970s in the wake of sharply higher costs for fossil fuels.
- Most of the spatial dispersion in average electricity prices across more than 3,000 U.S. counties can be accounted for in terms of average price differences among roughly 350 big utilities that supply electricity to the manufacturing sector.
- The spatial structure of prices has changed over time. The most rapid changes occurred from the middle 1970s to the early 1980s, probably as a result of sharp increases in oil, gas and coal prices. These fossil fuels play a much bigger role in electricity generation in some parts of the country than in others.
- Despite efforts to promote wholesale and retail price competition during the 1990s, and the substantial growth in wholesale electricity trade since the 1980s, the spatial structure of electricity prices during the 1980s and, especially, the 1990s is more stable than in earlier decades. Moreover, we find no evidence that the growth in wholesale electricity trade and supporting institutions eroded spatial price differences.

## References


Alvarado, Fernando and Shmuel Oren (2002). "Transmission System Operation and Interconnection". Issue paper from the "National Transmission Grid Study". Available at http://www.eh.doe.gov/ntgs/issuepapers/ISSUE_1.PDF.

Anderson, Douglas D. (1981). *Regulatory Politics and Electric Utilities: A Case Study in Political Economy.* Auburn House Publishing Company, Boston, MA.

*API Basic Petroleum Data Book, Vol. XXI, No. 2.* (2001). Washington D.C.

Bartelsman, Eric J. and Wayne Gray (1996). "The NBER Manufacturing Productivity Database". NBER Technical Working Paper 205, National Bureau of Economic Research, Cambridge, MA.

Borenstein, Severin (2002). "The Trouble With Electricity Markets: Understanding California's Restructuring Disaster". *The Journal of Economic Perspectives*, pp. 191-211.

Davis, Steven J., Cheryl Grim, John Haltiwanger and Mary L. Streitwieser (2003). "Construction of a Plant-Level Electricity Price Dataset from the 1963, 1967, and 172-2000 Census of Manufactures and Annual Survey of Manufactures." Center for Economic Studies Discussion Paper, U.S. Bureau of the Census, Washington, D.C. In progress.

DOE [Department of Energy] (2002). "National Transmission Grid Study". Available at http://www.eh.doe.gov/ntgs/reports.html.

EIA [Energy Information Administration] (2001a) "Annual Energy Review". Available at http://www.eia.doe.gov/emeu/aer/contents.html.

EIA [Energy Information Administration] (2001b) "State Energy Data Report 1999". DOE/EIA-0214(99).

EIA [Energy Information Administration] (2000a) "Inventory of Nonutility Electric Power Plants in the United States 1999". DOE/EIA-0095(99)/2.

EIA [Energy Information Administration] (2000b). "The Restructuring of the Electric Power Industry – A Capsule of Issues and Events". DOE/EIA-X037.

EIA [Energy Information Administration] (2000c). "The Changing Structure of the Electric Power Industry 2000: An Update". DOE/EIA-0562(00).

EIA [Energy Information Administration] (1999). "Issues in Midterm Analysis and Forecasting". DOE/EIA-0607(99).

EIA [Energy Information Administration] (1998). "Electric Trade in the United States 1996". DOE/EIA-0531(96).

EIA [Energy Information Administration] (1995). "Performance Issues for a Changing Electric Power Supply Industry". DOE/EIA-0586.

Gordon, Richard L. (1982). *Reforming the Regulation of Electric Utilities*. Lexington Books, Lexington, MA.

Halliday, David, Robert Resnick, and Kenneth S. Krane (1992). *Physics*. Volume 2 (extended), 4th ed., John Wiley and Sons, New York.

Hirsh, Richard F. (1999). *Power Loss: The Origins of Deregulation and Restructuring in the American Electric Utility System*. The MIT Press, Cambridge, MA.

Hirsh, Richard F. (1989). *Technology and Transformation in the American Electric Utility Industry*. Cambridge University Press, Cambridge.

Joskow, Paul L. (2003). "The Difficult Transition to Competitive Electricity Markets in the U.S.". Prepared for the conference "Electricity Deregulation: Where From Here?" at the Bush Presidential Conference Center. Texas A&M University, April 4, 2003 (revised May 2003).

Joskow, Paul L. (1997). "Restructuring, Competition and Regulatory Reform in the U.S. Electricity Sector". *The Journal of Economic Perspectives*, pp. 119-138.

Joskow, Paul L. (1989). "Regulatory Failure, Regulatory Reform, and Structural Change in the Electric Power Industry". *Brookings Papers on Economic Activity: Microeconomics*, pp. 125-208.

Joskow, Paul L. and Paul W. MacAvoy (1975). "Regulation and the Financial Condition of the Electric Power Companies in the 1970's". *American Economic Review*, pp. 295-301.

Joskow, Paul L. and Richard Schmalensee (1983). *Markets for Power: An Analysis of Electric Utility Deregulation*. The MIT Press, Cambridge, MA.

Wallace, Harold D. (2002). "Throw the Switch: The Technology of Electric Power". Smithsonian Institution. Available at http://americanhistory.si.edu/csr/powering/backthrw.htm.

Warkentin, Denise (1998). *Electric Power Industry In Nontechnical Language*. PennWell, Tulsa, OK.

White, Matthew W. (1996). "Power Struggles: Explaining Deregulatory Reform in Electricity Markets". *Brookings Papers on Economic Activity: Microeconomics*, pp. 201-25.

**Data Appendix**

This data appendix contains information on the creation of the electricity price database not included in Section 3. See Davis et al. (2003) for a detailed description of the creation of the electricity price database.

*A. Inactive Plants*

All inactive plants, those with salaries and wages (*SW*) equal to zero, were dropped.

*B. Industry Codes*

The electricity price database industry variable contains 1972 4-digit SIC codes for 1963, 1967, and 1972-1986 and 1987 4-digit SIC codes for 1987-2000. Corrections were made to the industry variable based on information in Davis, Haltiwanger, and Schuh (1996, p. 222). Additional corrections were made for consistency with the NBER-CES producer price index database.[27] Observations still containing invalid manufacturing 4-digit SIC codes after these corrections were dropped.

*C. Geography Codes*

The geography codes in the electricity price database are FIPS county and state codes. Several corrections were made to these codes including the correction of a problem with the FIPS state codes from 1963-1988 regarding Hawaii and the correction of FIPS county codes in 1986. The FIPS county codes were also adjusted for concordance over time and with the EIA data. Observations still containing invalid geography codes after these corrections were dropped.

*D. Measurement Issues in using the ASM*

There were some difficulties in specific years (e.g., 1983) with the survey responses. For example, in 1983 approximately 10 percent of respondents had the physical quantity of purchased electricity exactly equal to cost of purchased electricity suggesting that such respondents faced an incredible price of $1.00 per kilowatt-hour (the average industrial electricity price in 1983 was less than 10 cents per kilowatt-hour). Another data problem we encountered is that ASM plants are not readily identified in the 1967 Census of Manufactures. Using information from a variety of sources, we developed an algorithm to identify the 1967 ASM plants. A related problem is that ASM sample weights are not available in either 1963 or 1967. We also developed an algorithm to impute sample weights.

[27] The NBER-CES producer price indices are available at http://www.nber.org/nberces/nbprod96.htm. There is a price index value for each year and 4-digit SIC code.

**Table 1.** Selected Characteristics of the Electricity Price Data

<table>
<tr><td colspan="5">Years covered</td><td colspan="4">1963,1967,1972-2000</td></tr>
<tr><td colspan="5">Number of plant-level observations per year</td><td colspan="4">48,310 to 72,102</td></tr>
<tr><td colspan="5">Total number of annual plant-level observations[a]</td><td colspan="4">1,819,968</td></tr>
<tr><td colspan="5">Number of counties with manufacturing plants</td><td colspan="4">3,036</td></tr>
<tr><td colspan="5">Number of 4-digit Mfg. SIC industries (1972 / 1987)[b]</td><td colspan="4">447 / 459</td></tr>
<tr><td colspan="5">Number of “big” utilities[c]</td><td colspan="4">347</td></tr>
<tr><td colspan="5">Mean annual electricity purchases (GWh)[d]</td><td colspan="4">99.70 / 859.48</td></tr>
<tr><td colspan="5">Standard deviation annual electricity purchases (GWh)[d]</td><td colspan="4">333.75 / 2,396.90</td></tr>
<tr><td colspan="9">Quantiles of Annual Electricity Purchases (GWh), Shipments Weighted</td></tr>
<tr><td>1</td><td>5</td><td>10</td><td>25</td><td>50</td><td>75</td><td>90</td><td>95</td><td>99</td></tr>
<tr><td>.07</td><td>.30</td><td>.70</td><td>3.20</td><td>16.34</td><td>89.03</td><td>266.88</td><td>443.11</td><td>995.22</td></tr>
</table>

Notes:

[a] The initial sample contains 1,937,282 observations. We lose 448 observations because of invalid geography codes and 115,938 observations (6.0%) because of missing values for electricity price, total employment, value added or shipments. In addition, each year we trim .05% of the observations with the lowest electricity prices, which leads to a loss of 928 additional observations.

[b] We use 1972 SIC codes in 1963, 1967, and 1972-1986 and 1987 SIC codes in 1987-2000. See the CES working paper, “Construction of a Plant-Level Electricity Price Dataset from the 1963, 1967, and 1972-2000 Census of Manufactures and Annual Survey of Manufactures” for additional information.

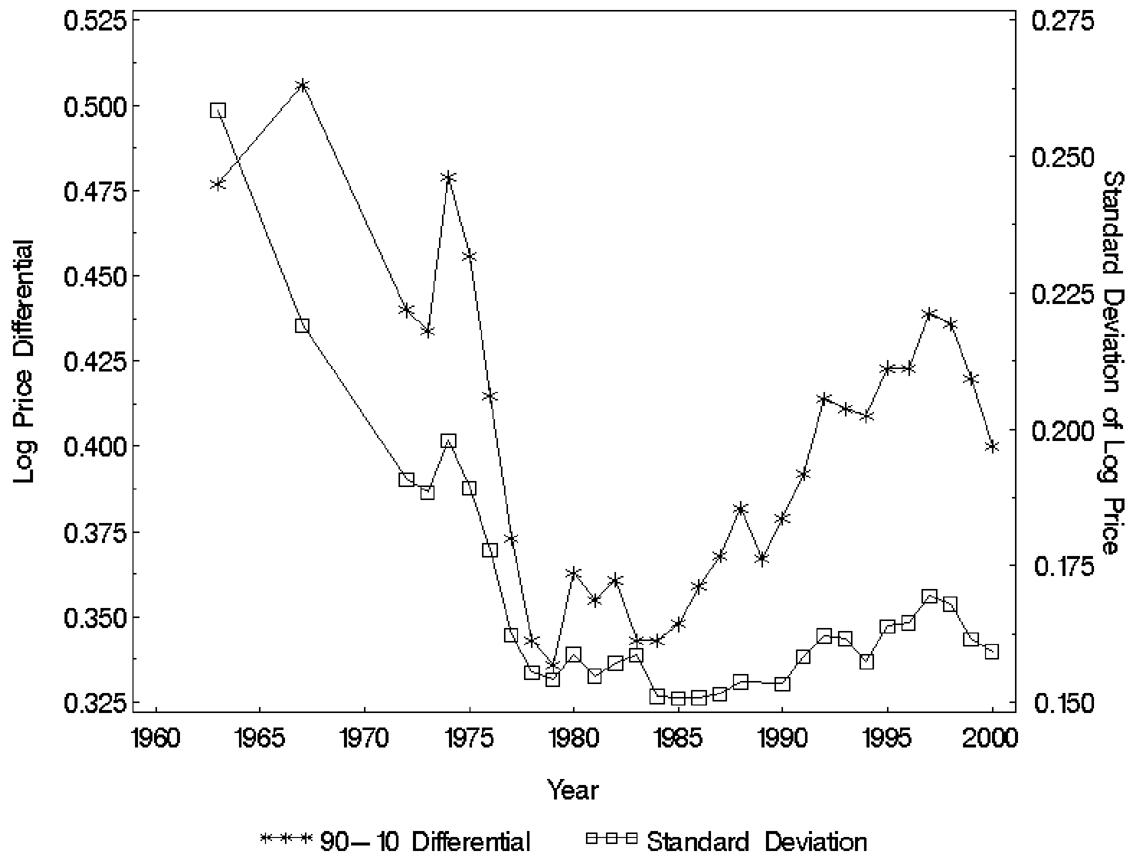
[c] By construction, a “big” utility does not cross state lines. Among the “big” utilities are three public power authorities: Tennessee Valley Authority (TVA), Bonneville Power Authority (BPA), and the New York Power Authority (NYPA). There are 337 “big” utilities not counting the public power authorities.

[d] The first number is computed from the shipments-weighted distribution of electricity purchases, and the second number is computed from the purchase-weighted (GWh) distribution.

**Table 2.** Variance Decompositions, Log Electricity Prices, Selected Years

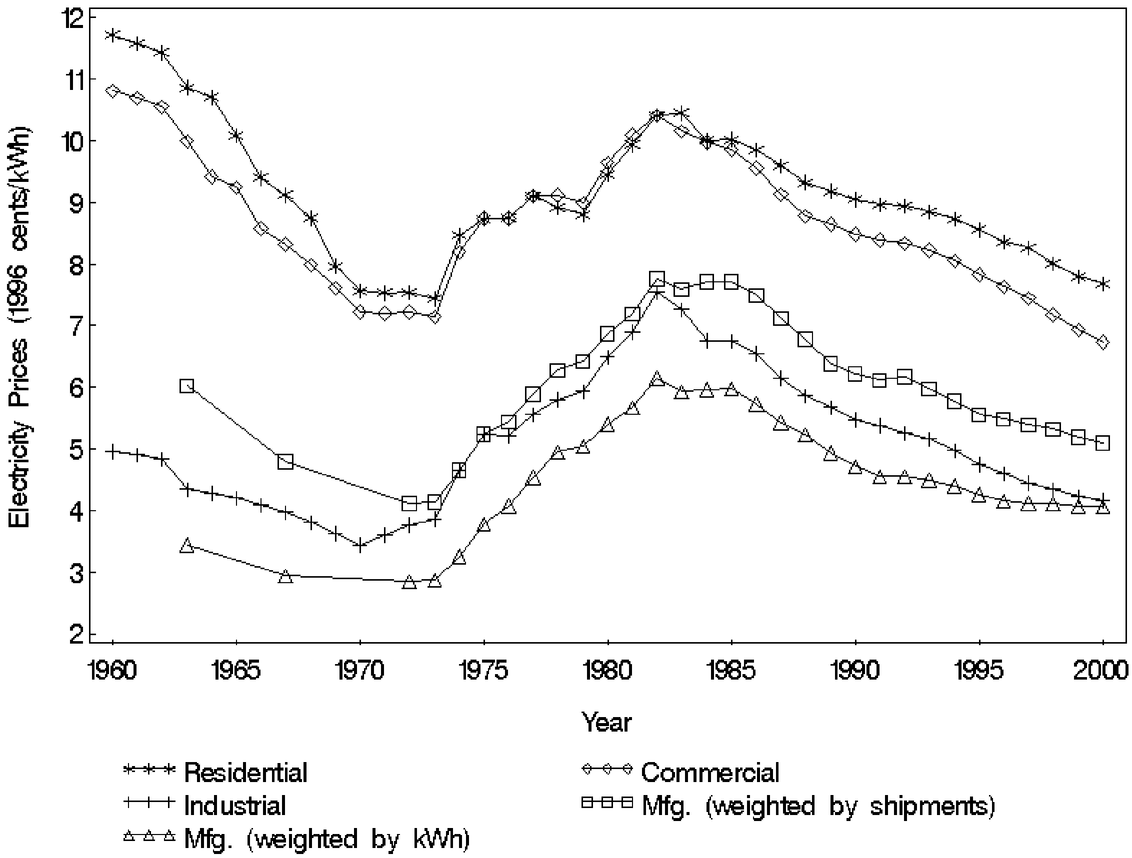
| | | 1963 | 1967 | 1972 | 1977 | 1982 | 1987 | 1992 | 1997 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Overall Standard Deviation** | .259 | .219 | .191 | .162 | .157 | .152 | .162 | .169 | .159 |
| | **County** | | | | | | | | | |
| 1 | Between Variance as % of Total | 18.9 | 29.0 | 31.4 | 53.0 | 66.3 | 53.8 | 61.6 | 57.2 | 54.2 |
| | Between Standard Deviation | .112 | .118 | .107 | .118 | .128 | .111 | .127 | .128 | .117 |
| | **Big Utility (BU)** | | | | | | | | | |
| 2 | Between Variance as % of Total | 9.0 | 19.0 | 21.8 | 42.3 | 55.5 | 43.7 | 50.4 | 46.5 | 42.9 |
| | Between Standard Deviation | .078 | .095 | .089 | .106 | .117 | .100 | .115 | .116 | .104 |
| | **State** | | | | | | | | | |
| 3 | Between Variance as % of Total | 4.2 | 12.1 | 16.7 | 34.8 | 45.8 | 36.1 | 42.7 | 39.1 | 35.8 |
| | Between Standard Deviation | .053 | .076 | .078 | .096 | .106 | .091 | .106 | .106 | .095 |
| | **NERC Regions** | | | | | | | | | |
| 4 | Between Variance as % of Total | 3.0 | 8.2 | 11.6 | 13.5 | 17.5 | 14.2 | 21.5 | 20.1 | 19.6 |
| | Between Standard Deviation | .045 | .063 | .065 | .060 | .066 | .057 | .075 | .076 | .071 |
| | **Usage Deciles** | | | | | | | | | |
| 5 | Between Variance as % of Total | 59.6 | 50.4 | 31.1 | 14.0 | 18.2 | 24.2 | 24.1 | 25.3 | 22.9 |
| | Between Standard Deviation | .200 | .156 | .106 | .061 | .067 | .075 | .080 | .085 | .076 |
| | **Usage Centiles** | | | | | | | | | |
| 6 | Between Variance as % of Total | 66.6 | 54.7 | 34.4 | 16.8 | 19.6 | 26.6 | 29.3 | 30.2 | 26.3 |
| | Between Standard Deviation | .211 | .162 | .112 | .067 | .070 | .078 | .088 | .093 | .082 |
| | **BU x Usage Deciles** | | | | | | | | | |
| 7 | Between Variance as % of Total | 69.8 | 64.4 | 52.5 | 55.7 | 68.3 | 61.3 | 66.7 | 63.6 | 61.8 |
| | Between Standard Deviation | .216 | .176 | .138 | .121 | .130 | .119 | .132 | .135 | .125 |
| | **BU x Usage Centiles** | | | | | | | | | |
| 8 | Between Variance as % of Total | 81.9 | 75.0 | 64.5 | 66.2 | 76.7 | 71.8 | 77.0 | 74.5 | 73.2 |
| | Between Standard Deviation | .234 | .190 | .153 | .132 | .138 | .128 | .142 | .146 | .136 |

Note: Statistics computed from the shipments-weighted distribution of electricity prices in the indicated year.



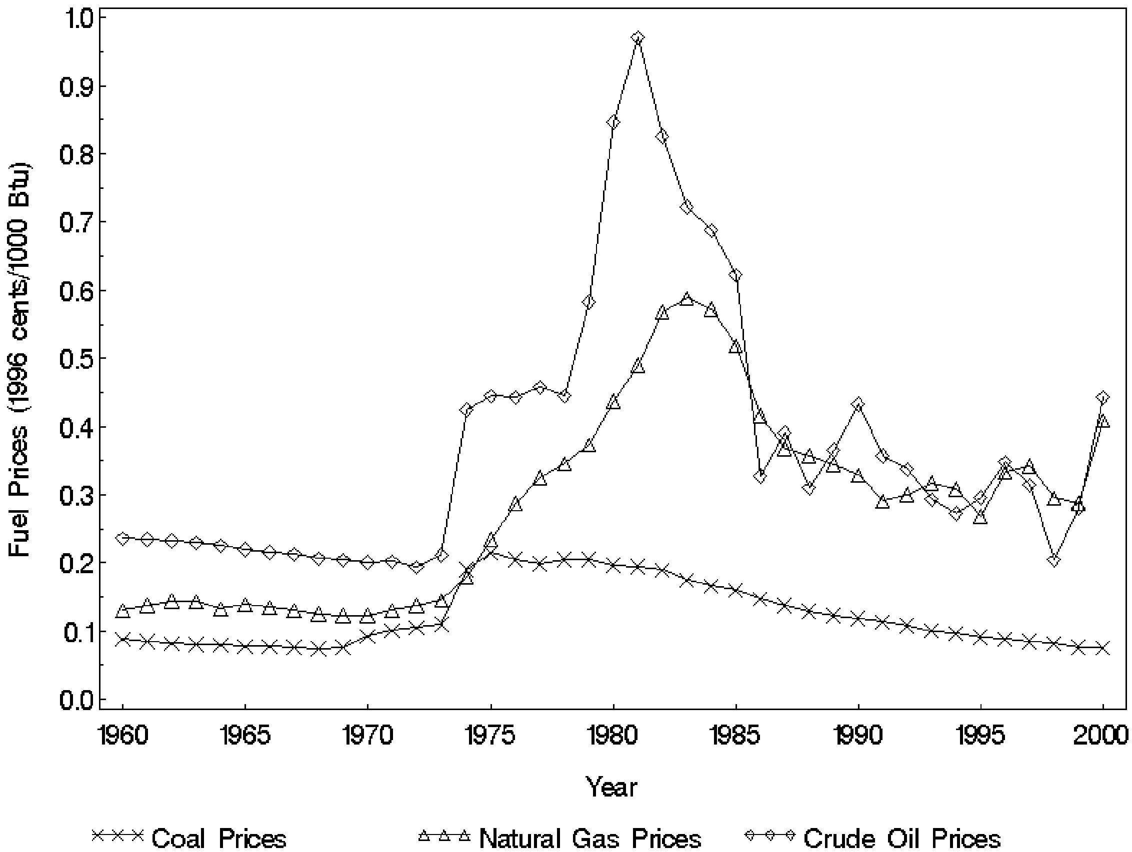

Source: Authors' calculations on plant-level data in the Annual Survey of Manufactures. Statistics computed on a shipments-weighted basis.

**Figure 1.** Electricity price dispersion, U.S. manufacturing, 1963-2000



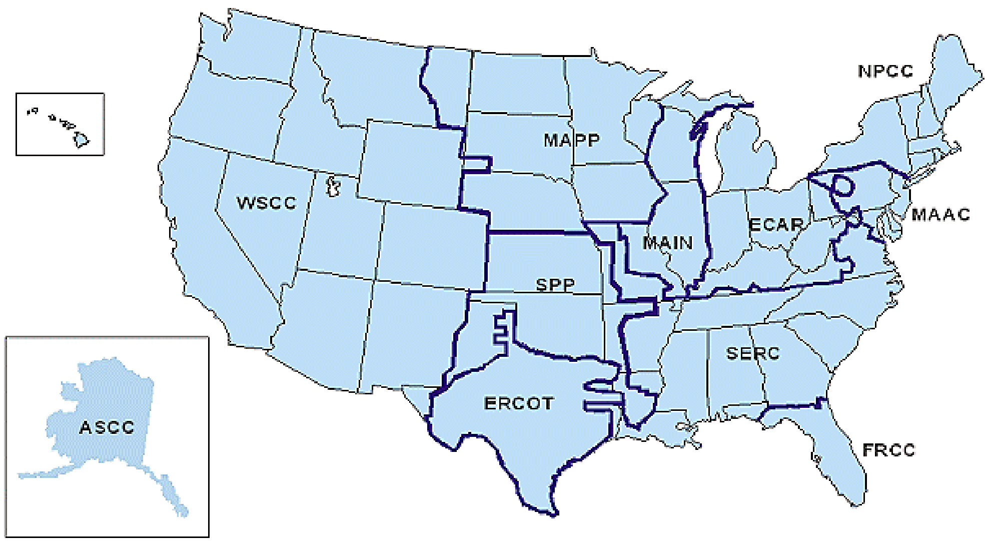

Source: Energy Information Administration and authors' calculation on data in the Annual Survey of Manufactures.

**Figure 2.** Real electricity prices by end-use sector, 1960-2000



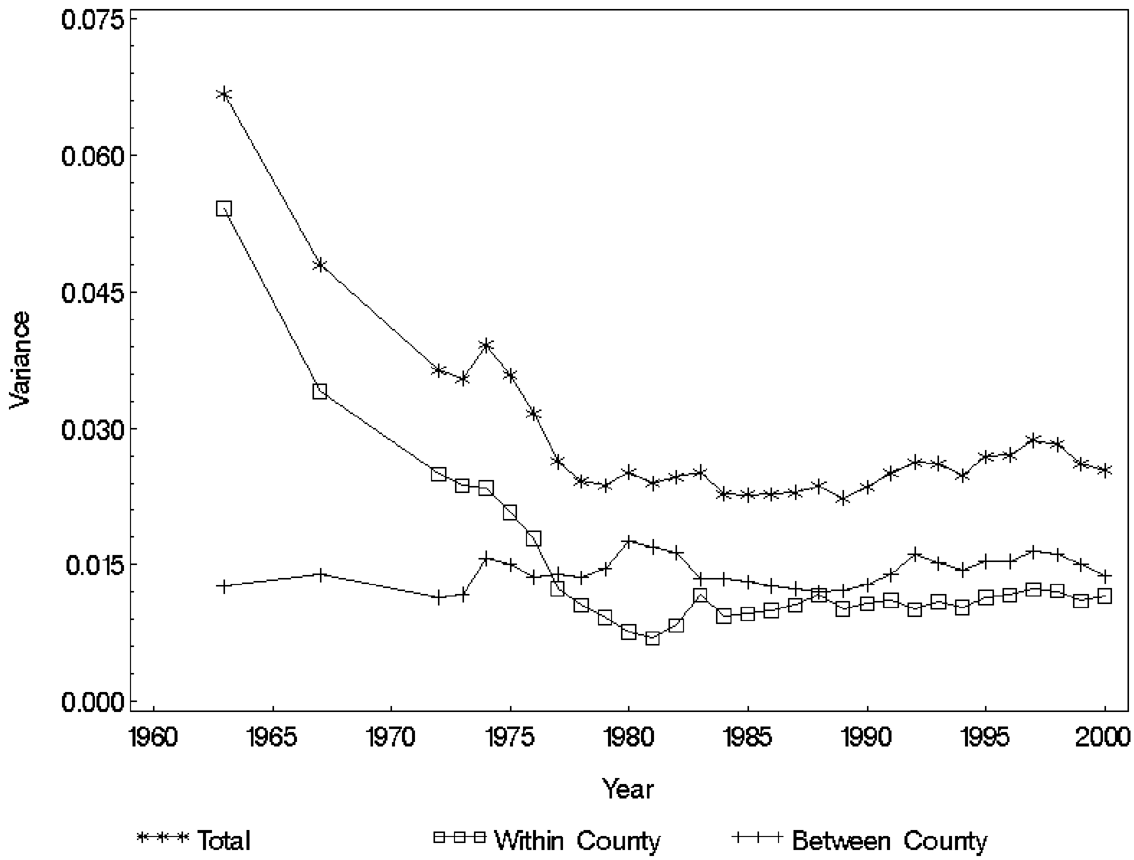

Sources: Energy Information Administration and API Basic Petroleum Data Book

**Figure 3.** Real fuel prices, 1960-2000



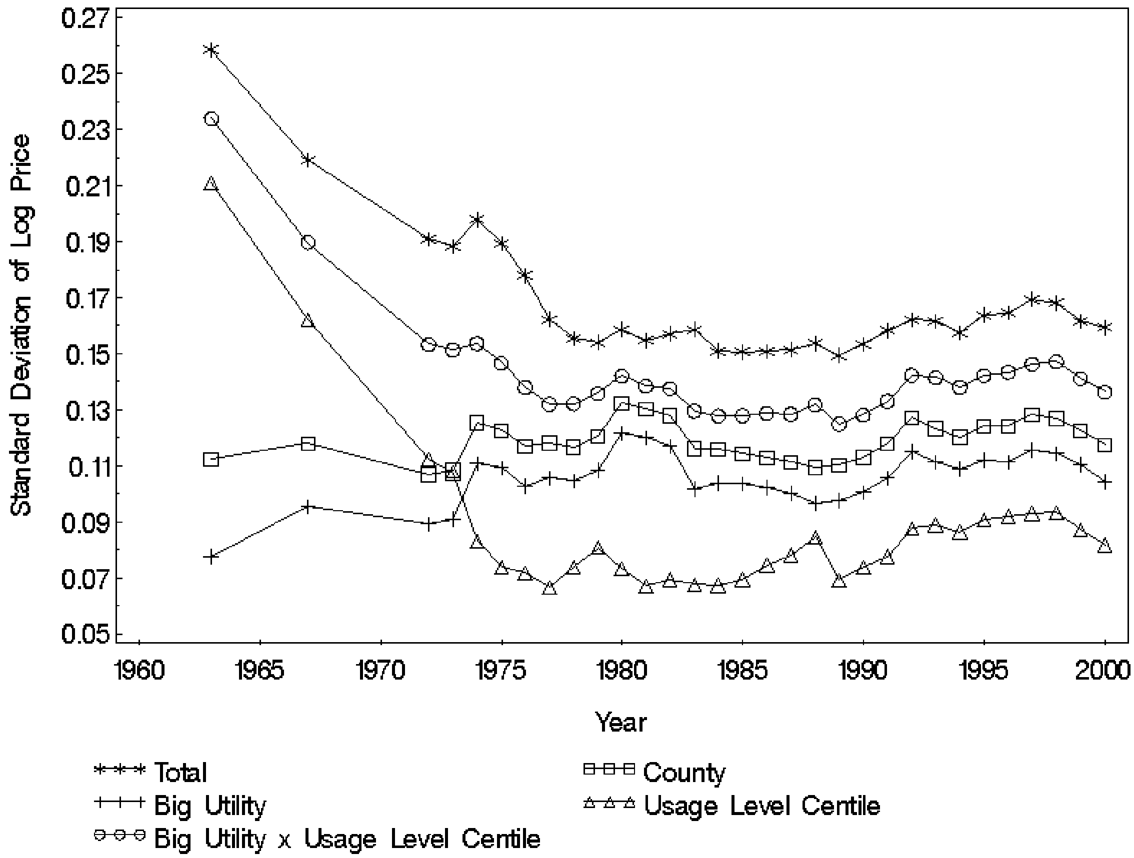

Source:  Energy Information Administration

**Figure 4.** NERC Region Boundaries



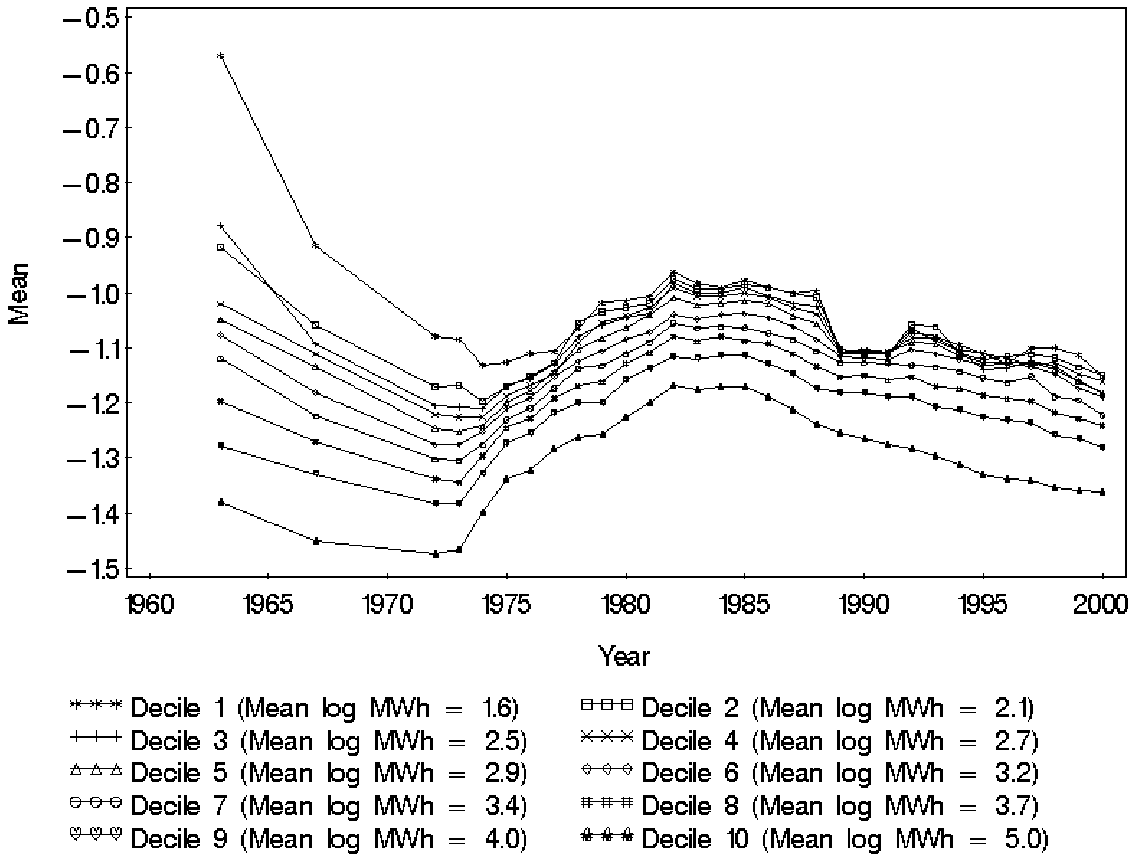

Source: Authors' calculations on plant-level data in the Annual Survey of Manufactures. Statistics computed on a shipments-weighted basis.

**Figure 5.** Variance of log electricity prices within and between counties, 1963-2000



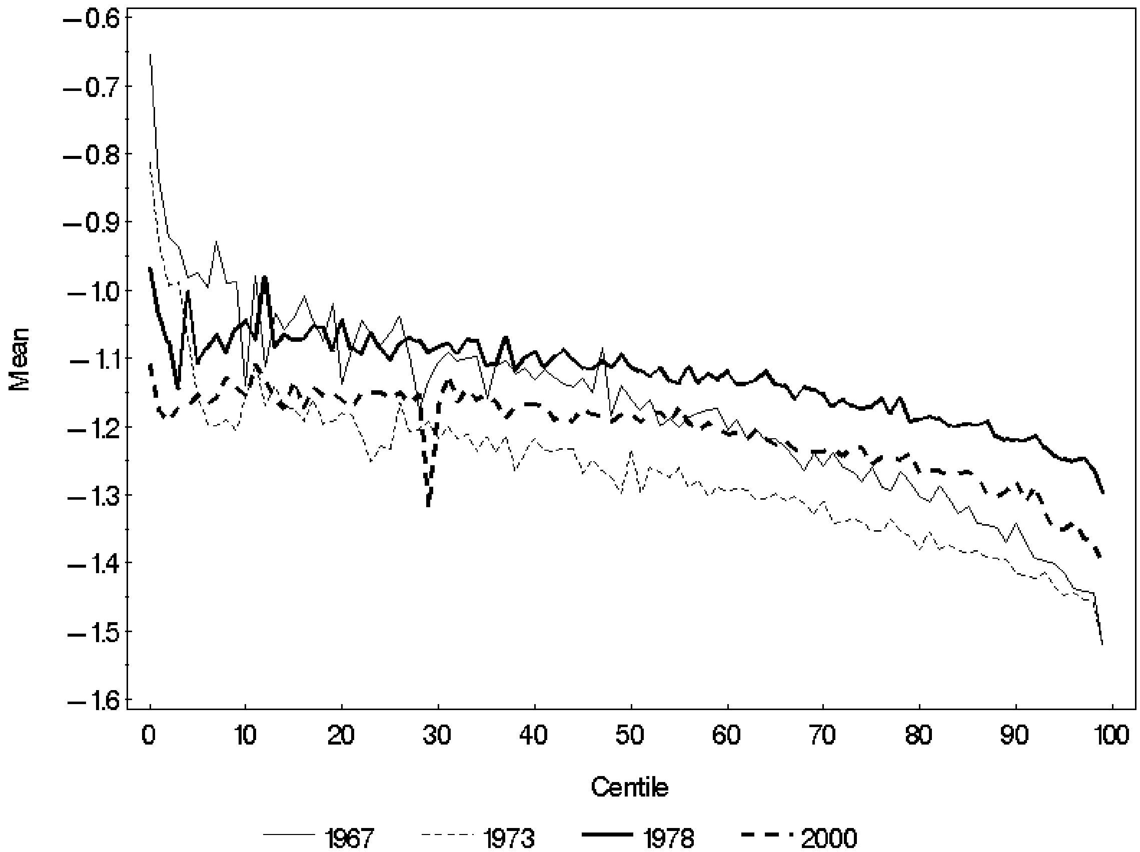

Source: Authors' calculations on plant-level data in the Annual Survey of Manufactures. Statistics computed on a shipments-weighted basis.

**Figure 6.** Electricity price dispersion across counties, usage level centiles, and utilities, 1963-2000



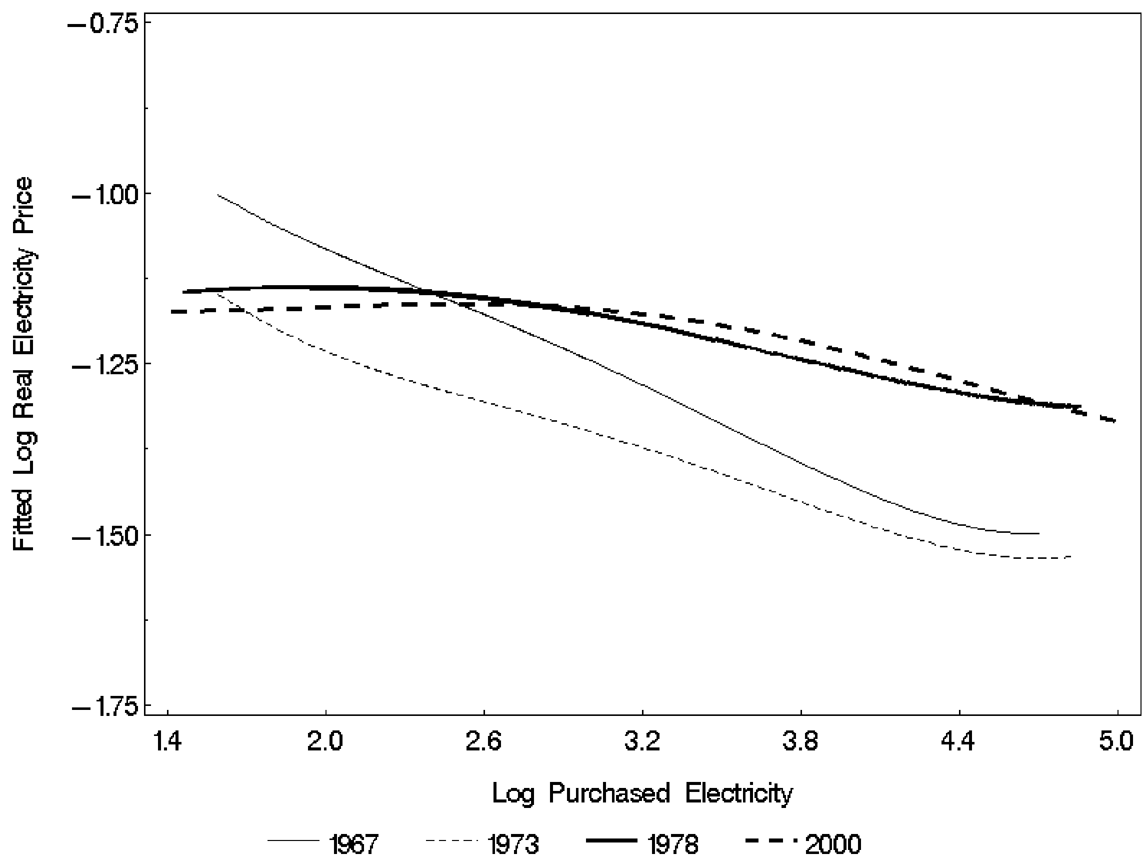

Source: Authors' calculations on plant-level data in the Annual Survey of Manufactures. Statistics computed on a shipments-weighted basis.

**Figure 7.** Mean of log real electricity prices by usage deciles, 1963-2000



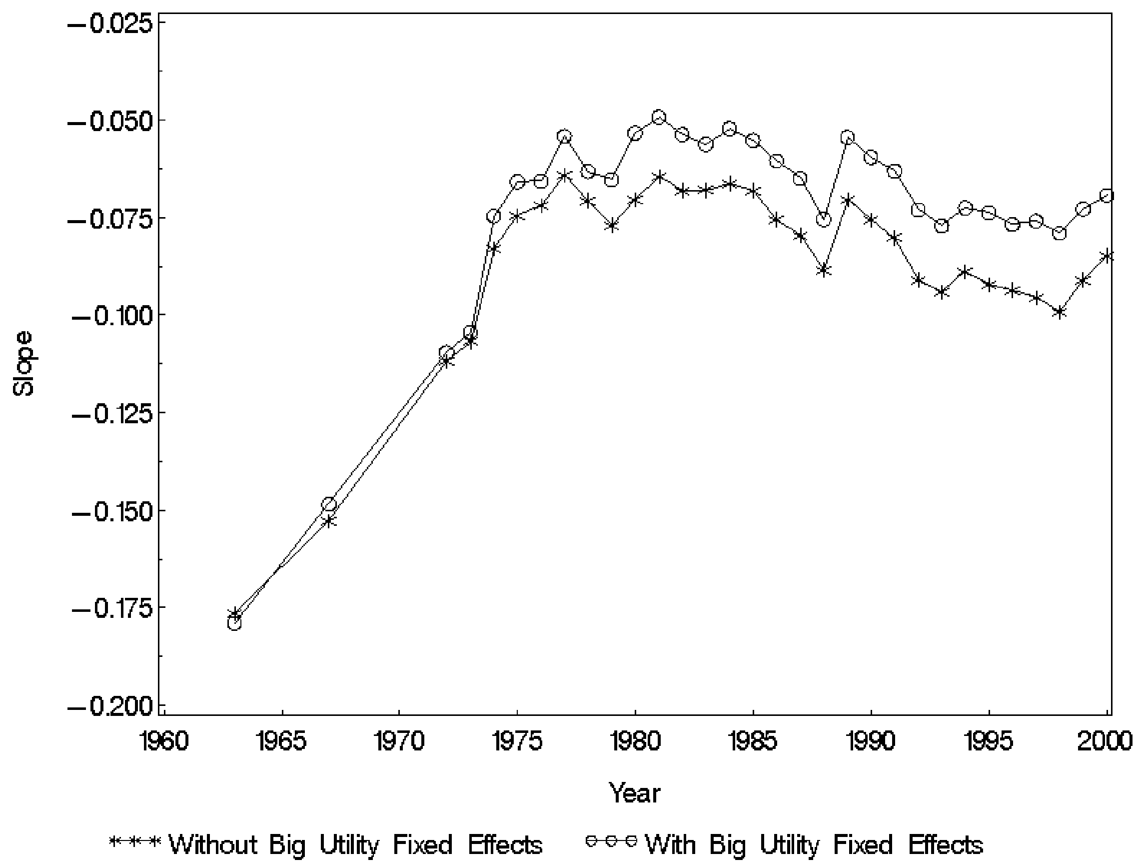

Source: Authors' calculations on plant-level data in the Annual Survey of Manufactures. Statistics computed on a shipments-weighted basis.

**Figure 8a.** Mean of log real electricity prices by usage centiles, selected years



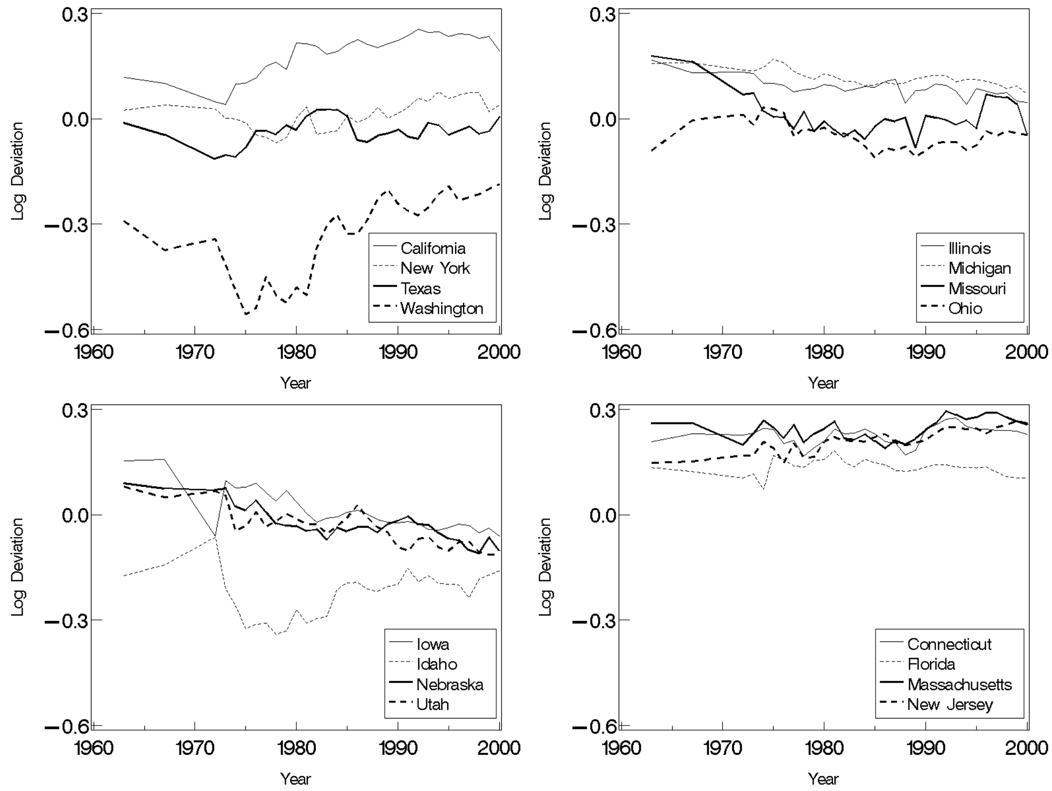

Source: Authors' calculations on plant-level data in the Annual Survey of Manufactures. Statistics computed on a shipments-weighted basis.

**Figure 8b.** Log electricity price fitted to a quartic polynomial in plant's purchased electricity, selected years



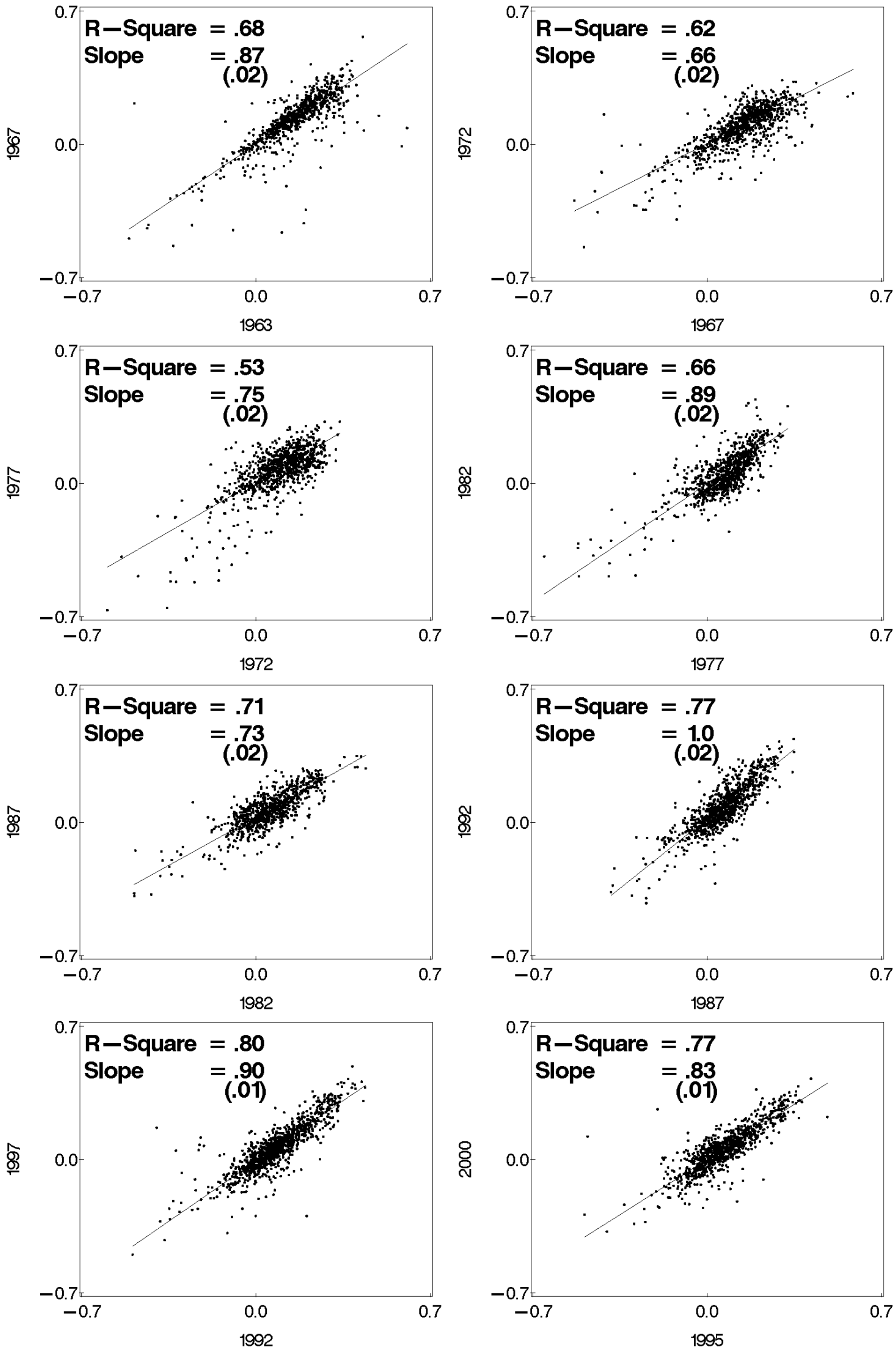

Source: Authors' calculations on plant-level data in the Annual Survey of Manufactures. Statistics computed on a shipments-weighted basis.

**Figure 9.** Slope coefficients, log electricity price regressed on log purchases, 1963-2000



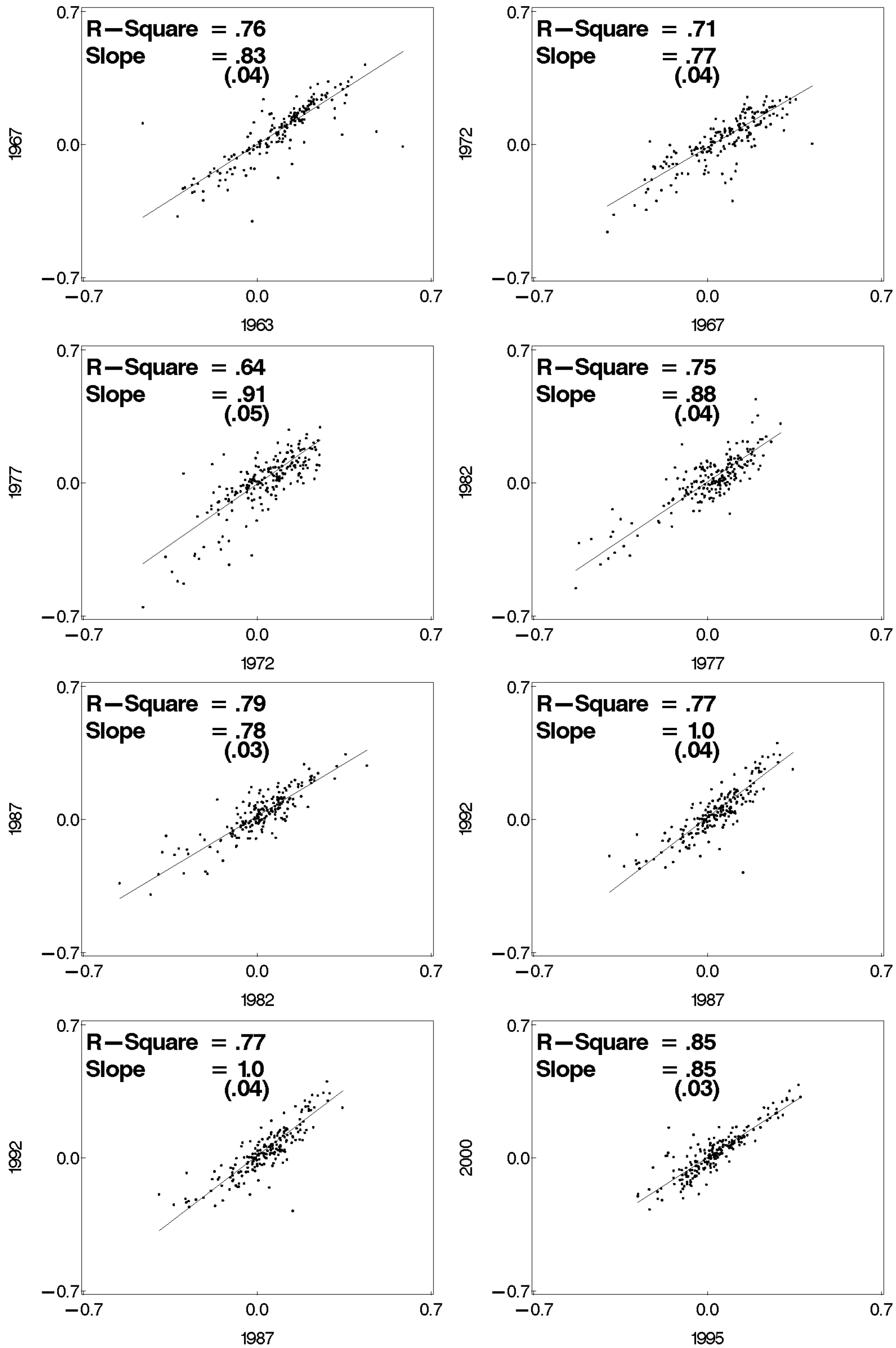

Source: Authors' calculations on plant-level data in the Annual Survey of Manufactures. Statistics computed on a purchase-weighted basis.

**Figure 10.** Deviation of state log electricity price from U.S. log electricity price, 1963-2000, selected states




Source: Authors' calculations on plant-level data in the Annual Survey of Manufactures. Statistics computed on a purchase-weighted basis.

**Figure 11.** Scatter plots of county effects, selected year pairs




Source: Authors' calculations on plant-level data in the Annual Survey of Manufactures. Statistics computed on a purchase-weighted basis.

**Figure 12.** Scatter plots of big utility effects, selected year pairs